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Application of silicone based elastomers for manufacturing of Green Fiber Bottle

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1. Introduction

Due to ever-increasing demand of sustainable products, eco-friendly packaging solutions are finding their importance in the paper packaging industry. Green Fiber Bottle (GFB) is an alternative to plastic, glass and metal based packaging for beverages. The tool concept for manufacturing of paper bottle uses a silicone based elastomer as the core. The expansion of core in the tool resists shrinkage of paper during drying as well as helps in obtaining good fiber compaction. The feasibility of the tool concept in the production of GFB is discussed in this work.

2. Manufacturing Process

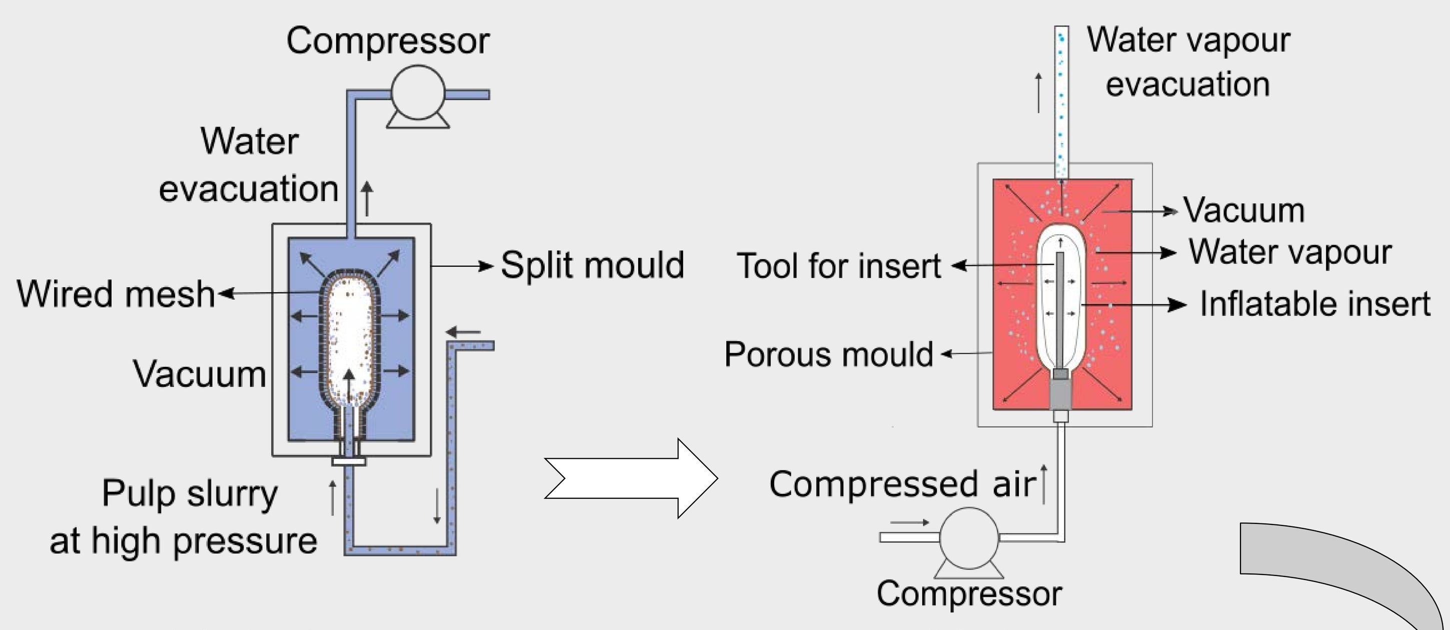


Fig. 1 (a) The forming process Fig. 1 (b) The drying process

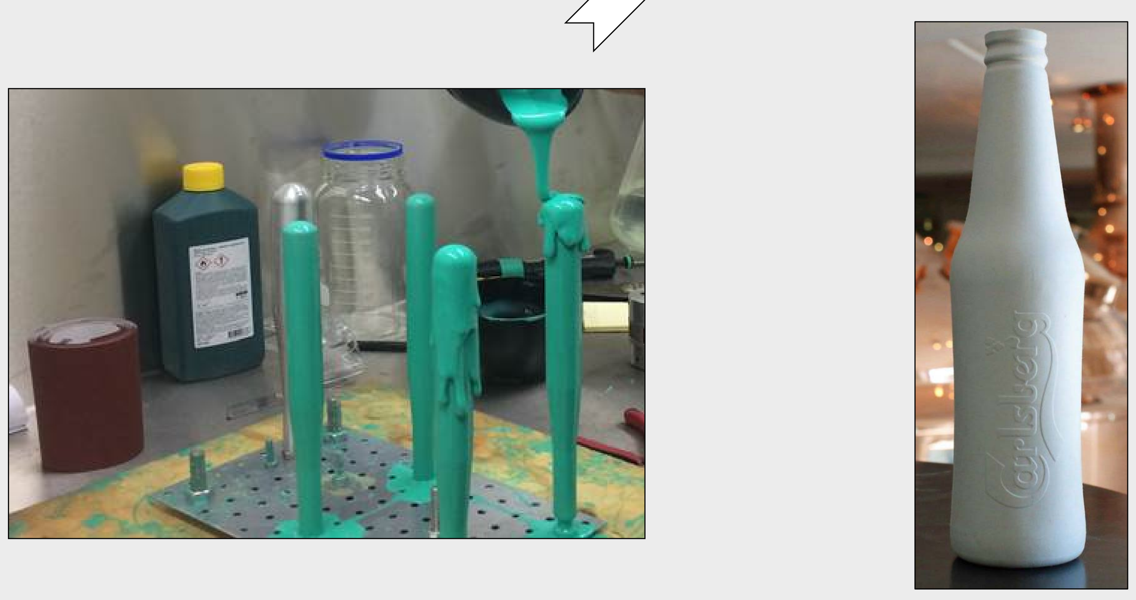
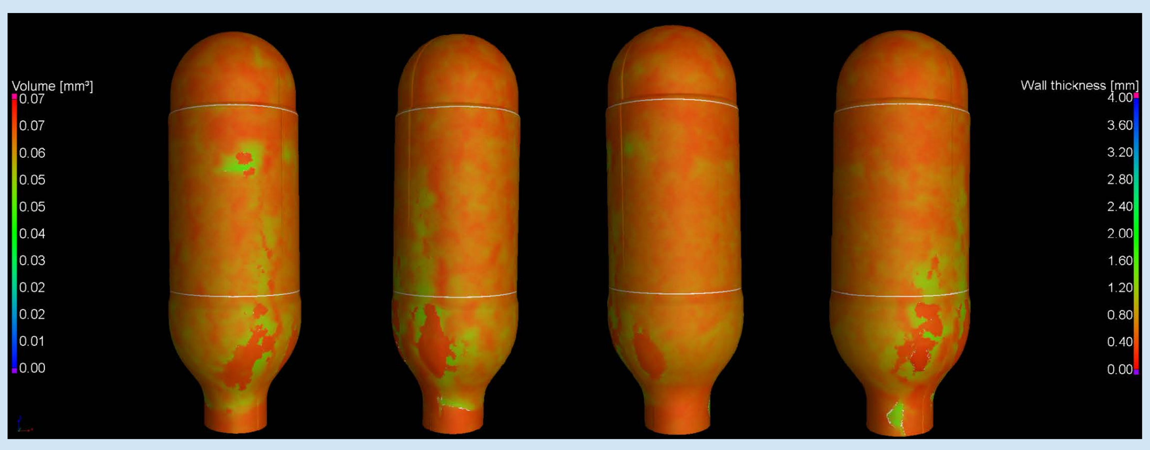


Fig. 2 Manufacturing of silicone core (on left) and a finished GFB (on right)

3. Fiber compaction

Wall thickness analysis using Computed Tomography (CT) verified uneven fiber compaction in the GFB.



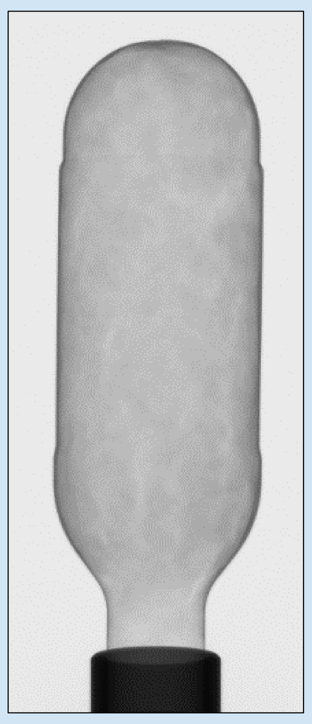


Fig. 3 Wall thickness analysis of GFB (on left) and CT scanned specimen (on right)

4. Feasibility of the tool concept

The hyperelastic behaviour of the silicone core is defined by Deformation energy function (W). To simulate the inflating action of the core, *Yeoh's model* is used for modelling W.

Governing equations

$$\mathbf{F} = \frac{\partial \mathbf{x}}{\partial \mathbf{X}};\ \boldsymbol{\sigma} = 2\mathbf{F}\frac{\partial \mathbf{W}}{\partial \mathbf{C}}\mathbf{F}^{\mathbf{T}}$$

F = Deformation gradient tensor

C = Cauchy – Green tensor

x and **X** = Spatial and material coordinates

$$\boldsymbol{W = C_{10}(I_1 - 3) + C_{20}(I_1 - 3) + C_{30}(I_1 - 3)}$$

Where **I** = trace of C; $\boldsymbol{C_{10}}$, $\boldsymbol{C_{20}}$, $\boldsymbol{C_{30}}$ to be determined by curve fitting.

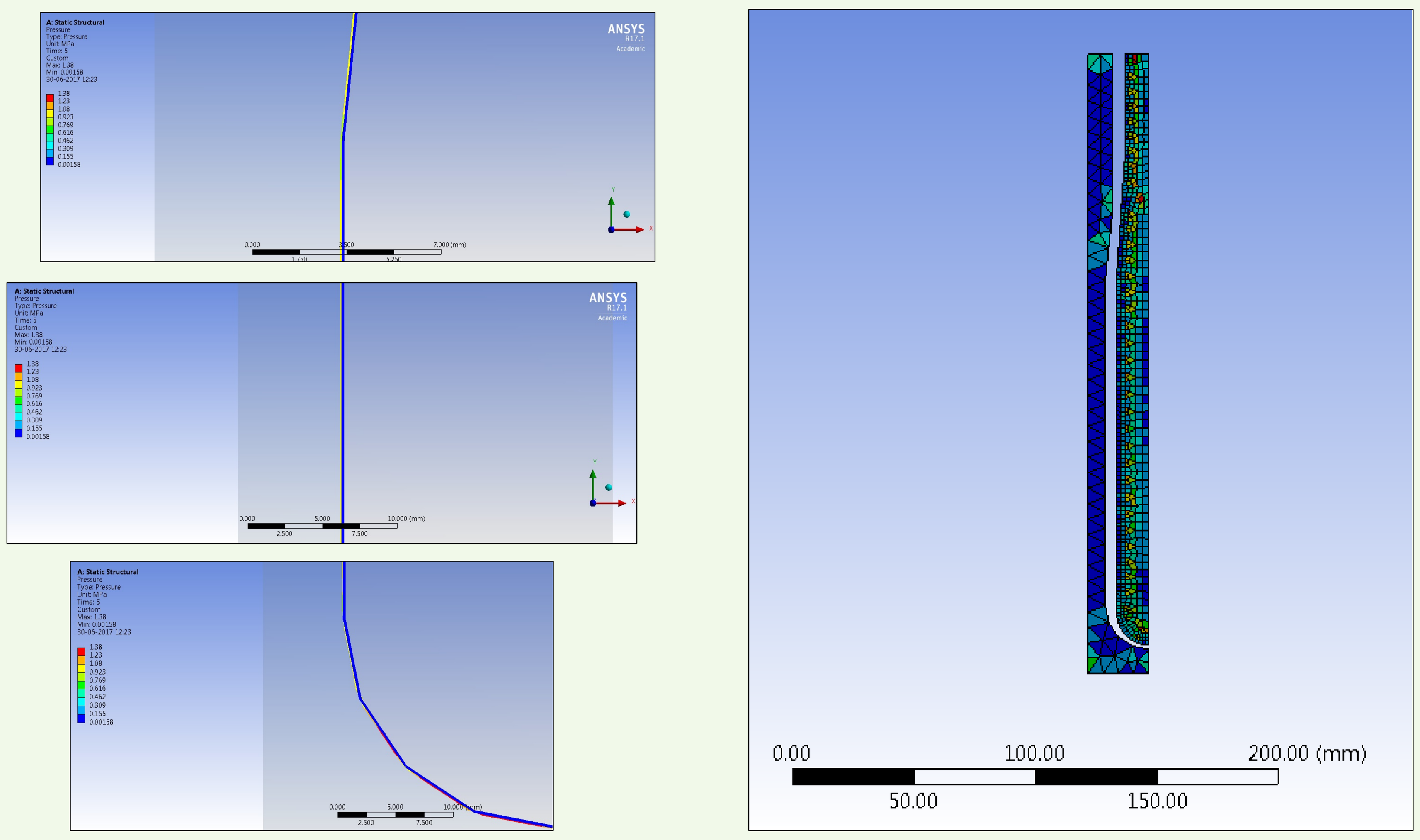


Fig. 4 Finite Element Model (FEM) based analysis of contact pressure (on left) and FEM model (on right)

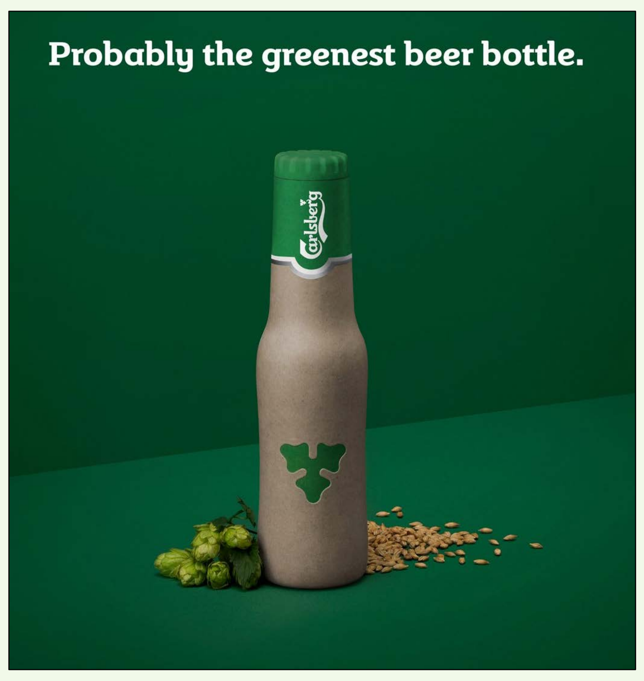


Fig. 5 Bursting of GFB (on left) and a prototype of GFB (on right)

Bursting of bottle in the non-conformal areas was verified. This is due to non-uniform contact pressure in the tool leading to uneven fiber compaction.

5. Conclusions and Future work

The FEM analysis predicts generation of uneven contact pressure on tool from the silicone core. The contact pressure is relatively less in the area of sharp curvature as compared to rest of the bottle geometry. The uneven contact pressure gives rise to uneven wall thickness. Wall thickness analysis using Industrial X-ray CT verifies the occurrence of 'weak zones' in the bottle. The average cut-off pressure that a bottle made of recycled newsprint pulp can withstand is 5 bar. The strength of GFB can be enhanced by optimizing the shape of silicone core, thereby offering uniform wall thickness. Moreover, a stronger pulp material is desirable and is being investigated for the production of GFB.

6. Acknowledgement

The work has been carried out as a part of the project titled "Impulse Drying of cardboard moulded 3D structures" with the support from Innovations Fund Denmark (Grant no. 5106-00006B). The authors would also like to acknowledge the help and support from EcoXpac and Carlsberg group for carrying out this work.